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Global climate predictions: forecast drift and bias adjustment issues

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PREFACE

Many of the ideas in this presentation were discussed at the SPECS/PREFACE/WCRP workshop:

http://www.bsc.es/es/earth-sciences/events/specsprefacewcrp-workshop

- The objective was to show the latest results on the sources and conditions behind the initial shock and drift, to assess the impact on the forecast quality, and to organise some coordinated work taking advantage of the WCRP's Working Group on Seasonal-to-Ineranannual Prediction (WGSIP) initial shock and drift project: the Long Range Forecast Transient Intercomparison Project.
- Sensitivity to the initialisation methodology (coupled initialisation) and product (GSOP) was central.
- A discussion for recommendations for bias adjustment in CMIP6 also took place.

Climate prediction time scales

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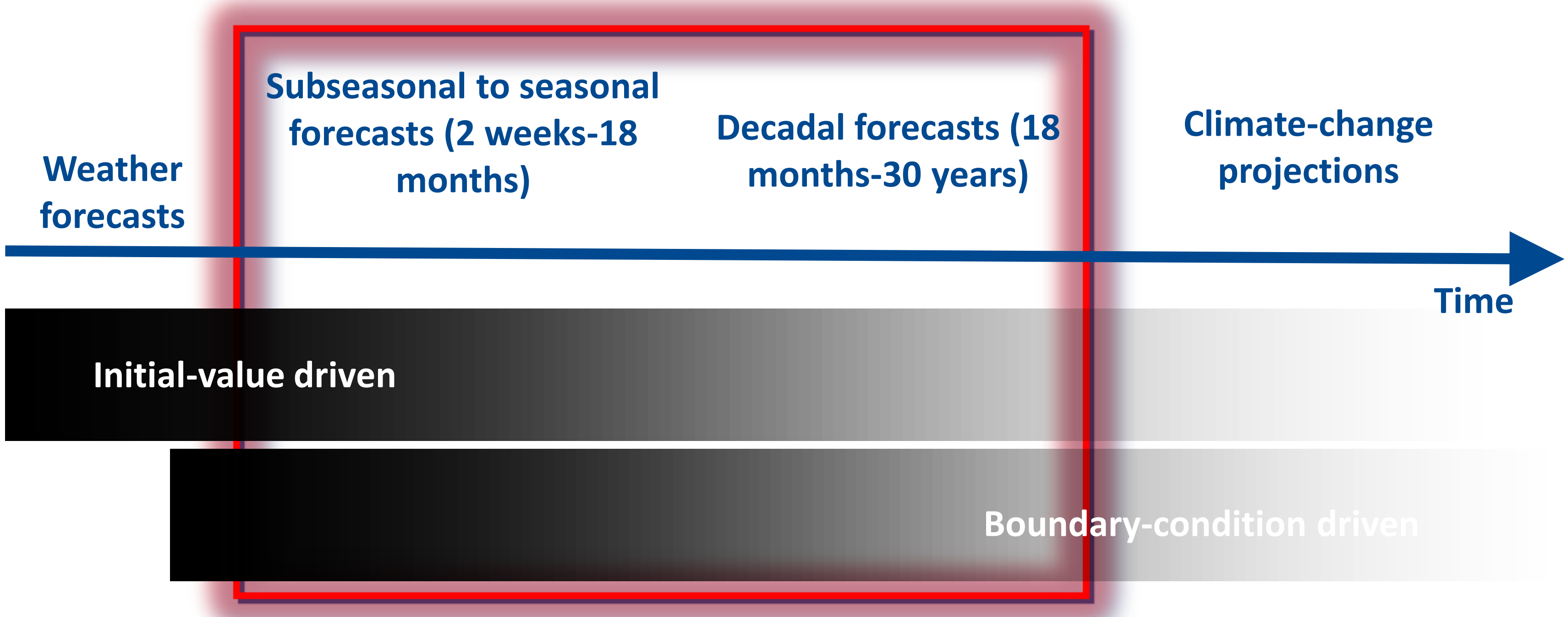
Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and validation/verification.



Adapted from Meehl et al. (2009)

The type of signal to be predicted

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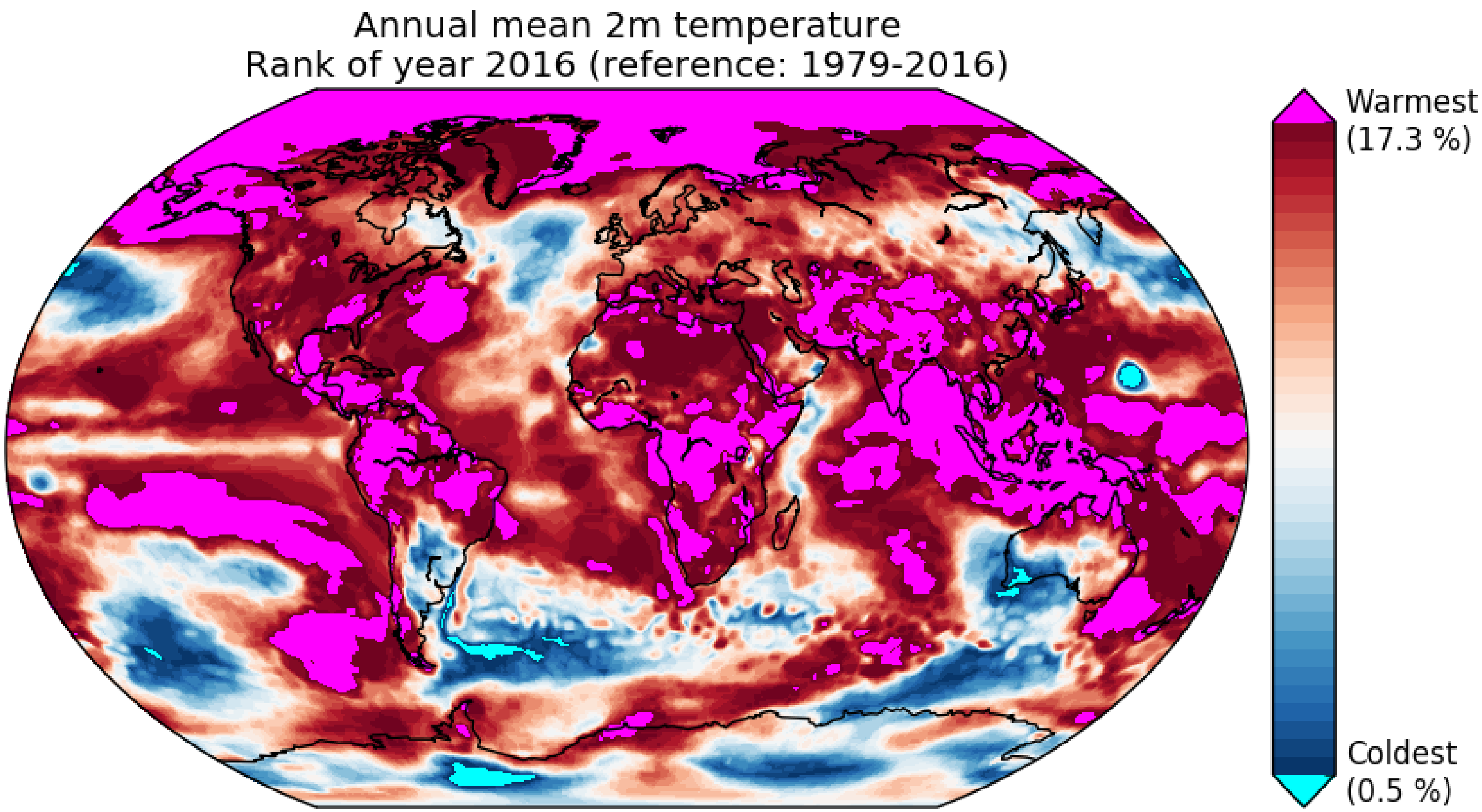
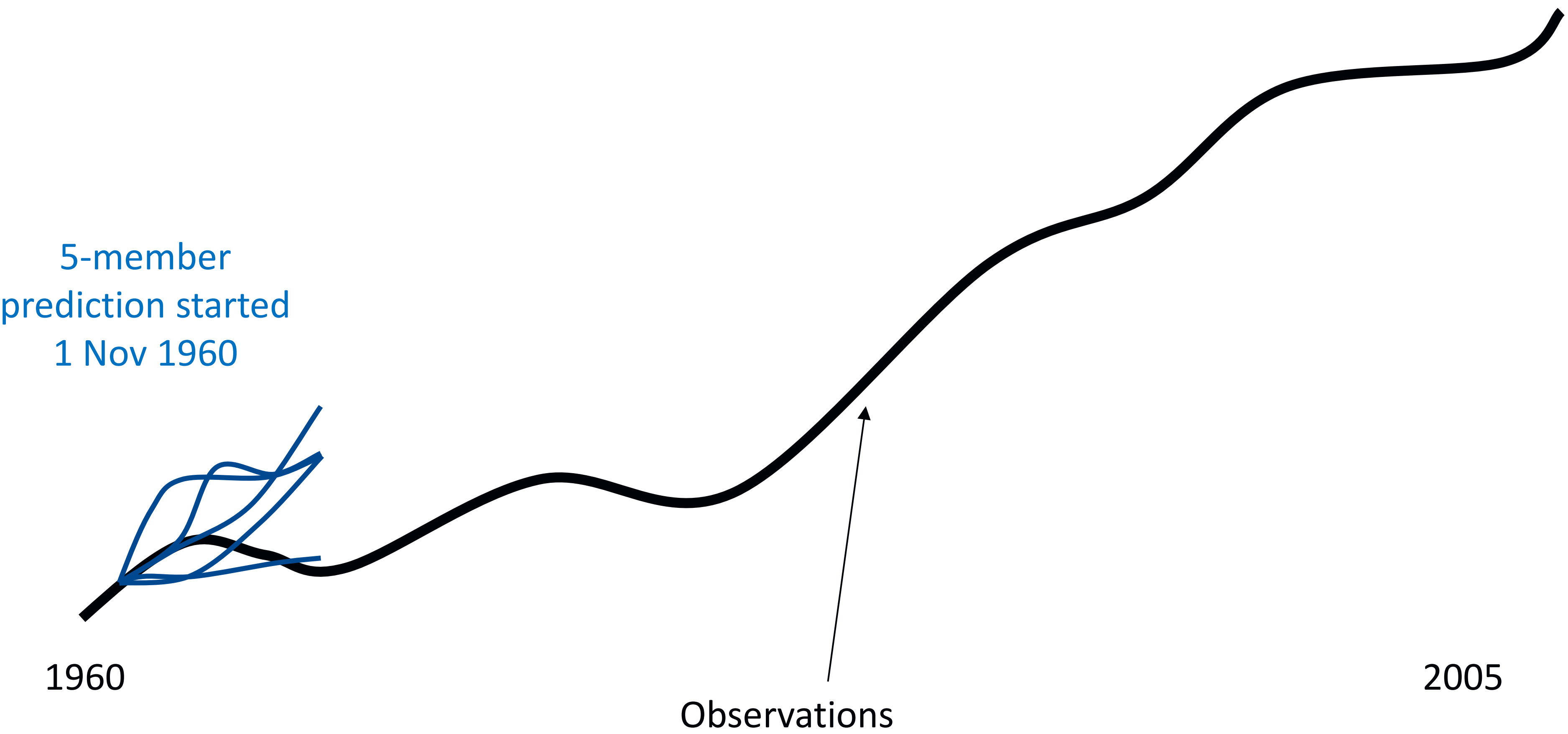
Ranking of the 2016 annual mean temperature over the last 37 years from ERA Interim.

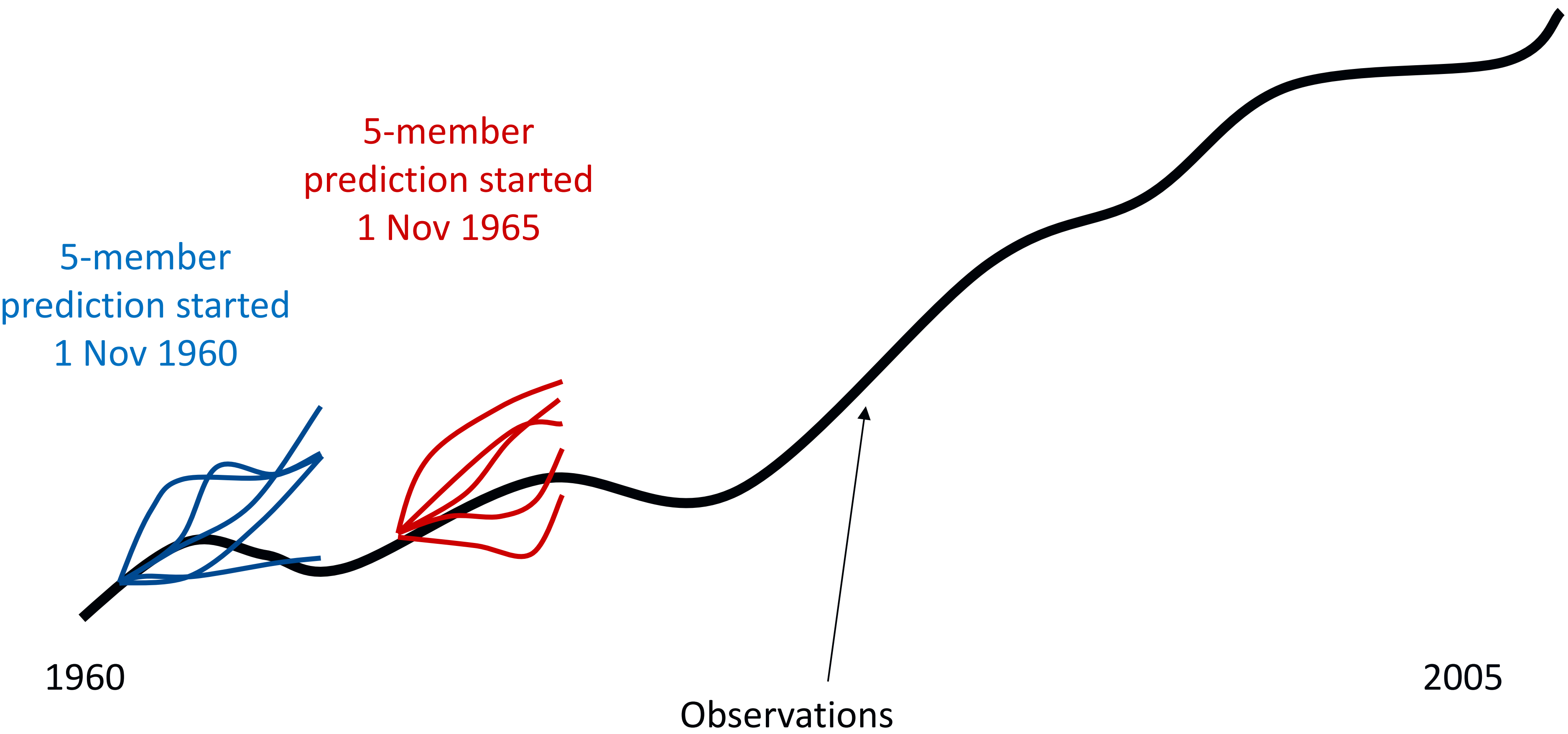


Data: ERA-Interim. Figure: F. Massonnet - BSC

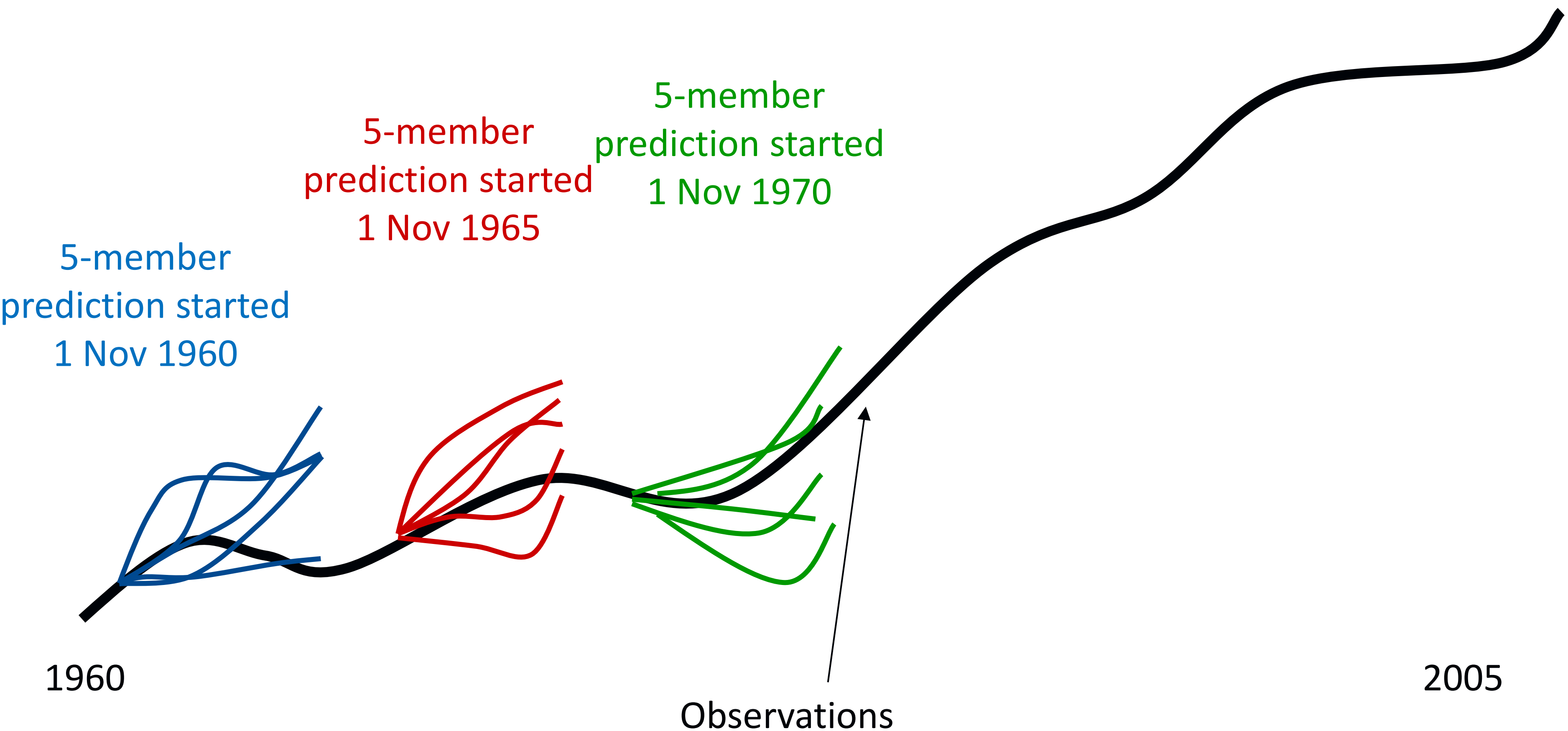
Climate predictions



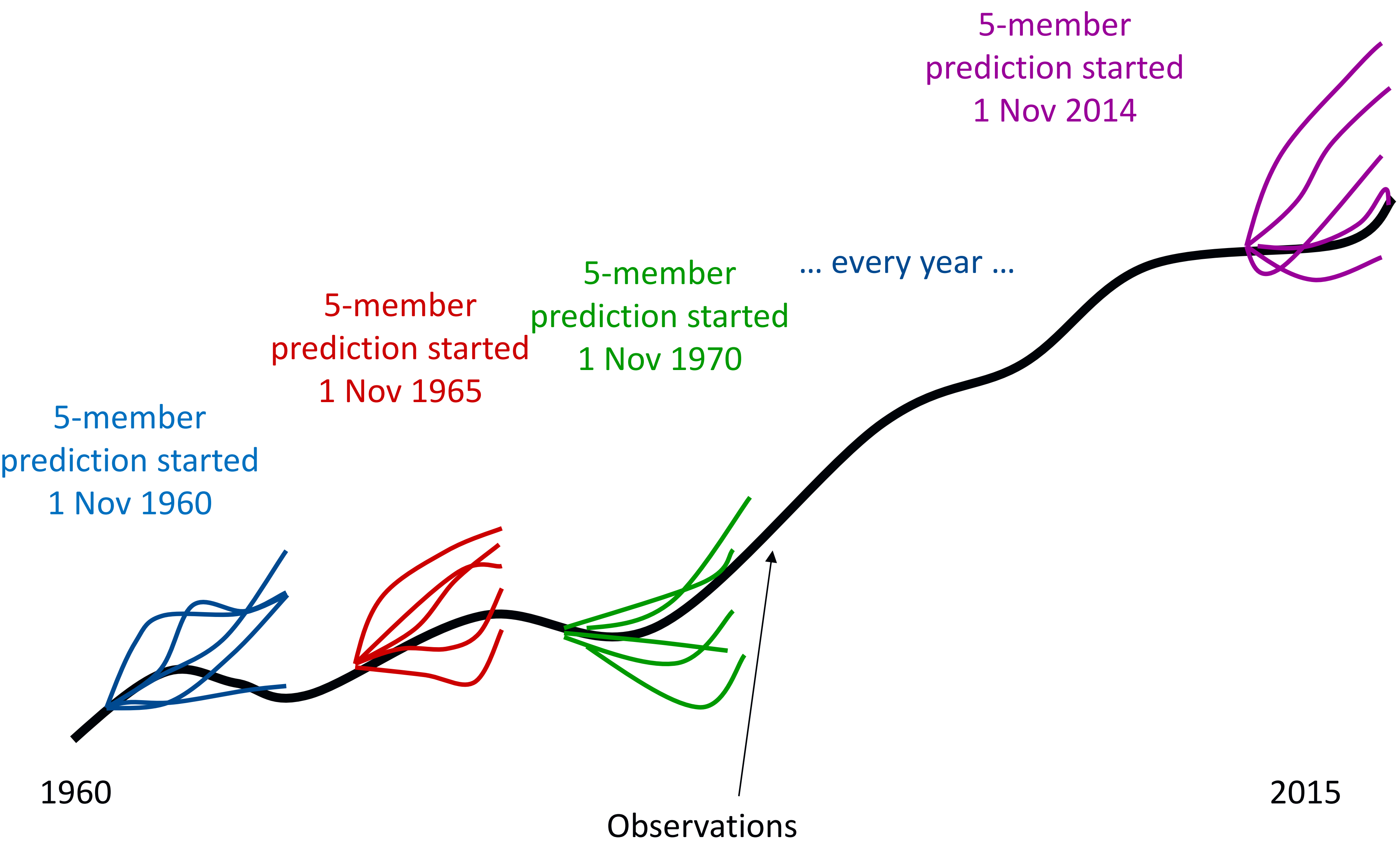
Climate predictions



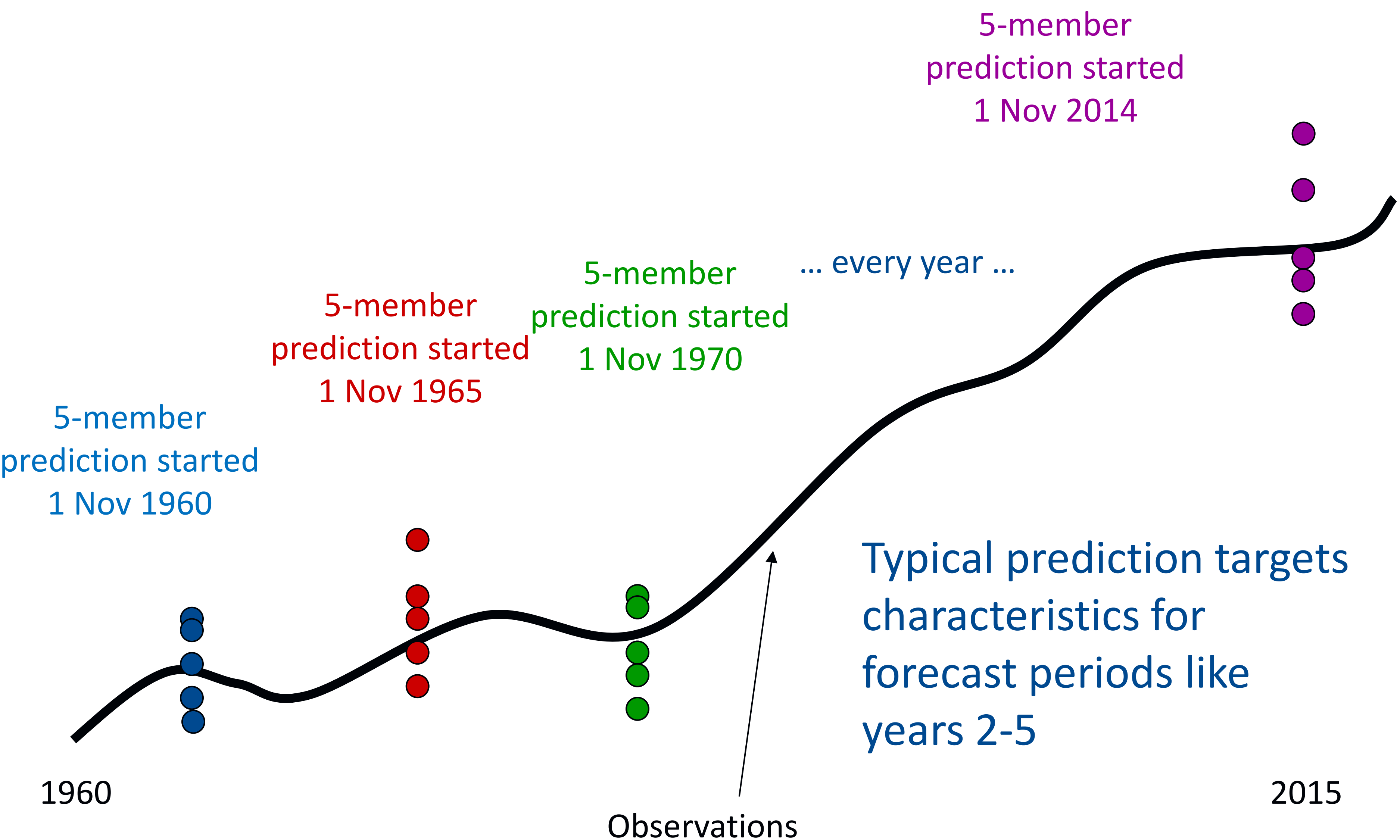
Climate predictions



Climate predictions



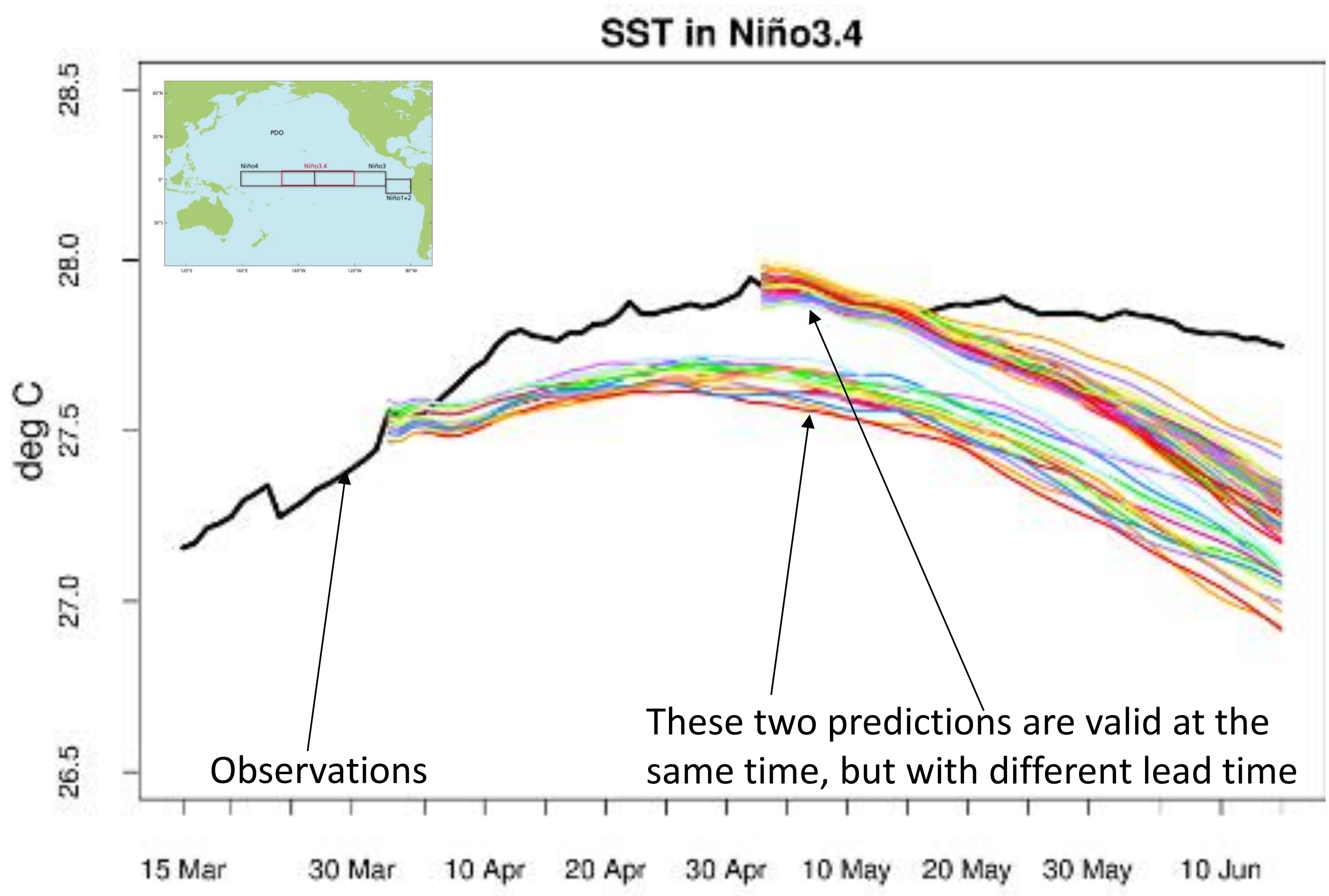
Climate predictions



Typical prediction targets characteristics for forecast periods like years 2-5

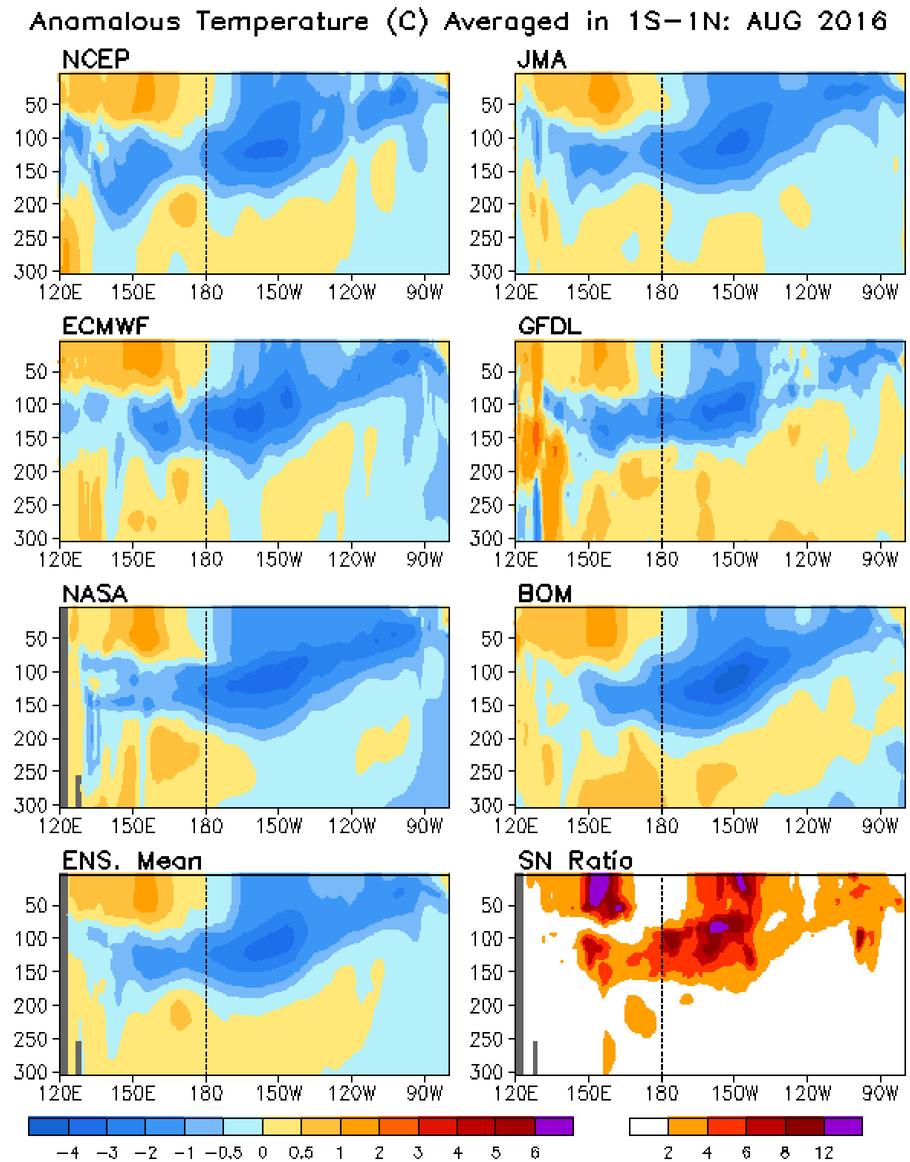
A simple illustration of a forecast

SST predictions over the Niño3.4 region from ECMWF System 4 starting on the 1st of April and May of a particular year.



Initial condition uncertainty

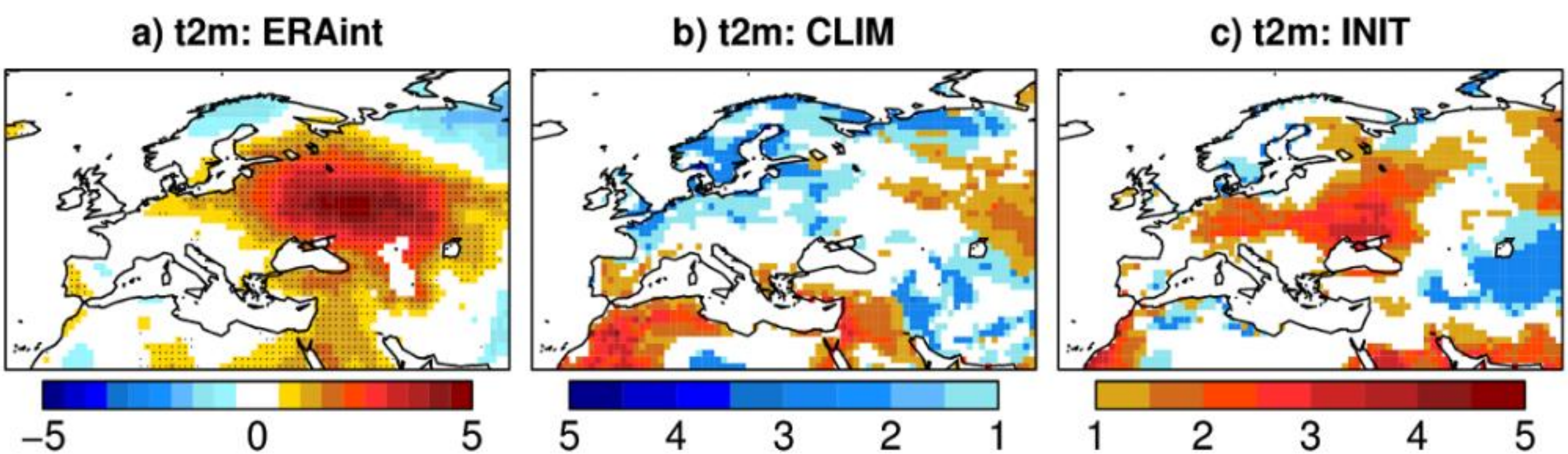
- Real-time ocean analysis comparison. Temperature anomalies along the Equator based on 1981-2010 climatology.
- Large spread in real-time initial conditions (similar message from CLIVAR-GSOP).
- Good observations of the whole system are absolutely fundamental for accurate predictions.
- Initial condition uncertainty taken into account in ensemble systems.



http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Skill and land-surface initialisation

JJA near-surface temperature anomalies in 2010 from ERAInt (left) and odds ratio from experiments with a climatological (centre) and a realistic (right) land-surface initialisation. Results for EC-Earth2.3 started in May with initial conditions from ERAInt, ORAS4 and a sea-ice reconstruction over 1979-2010.



Prodhomme et al. (2015, Clim. Dyn.)

Skill and land-surface initialisation

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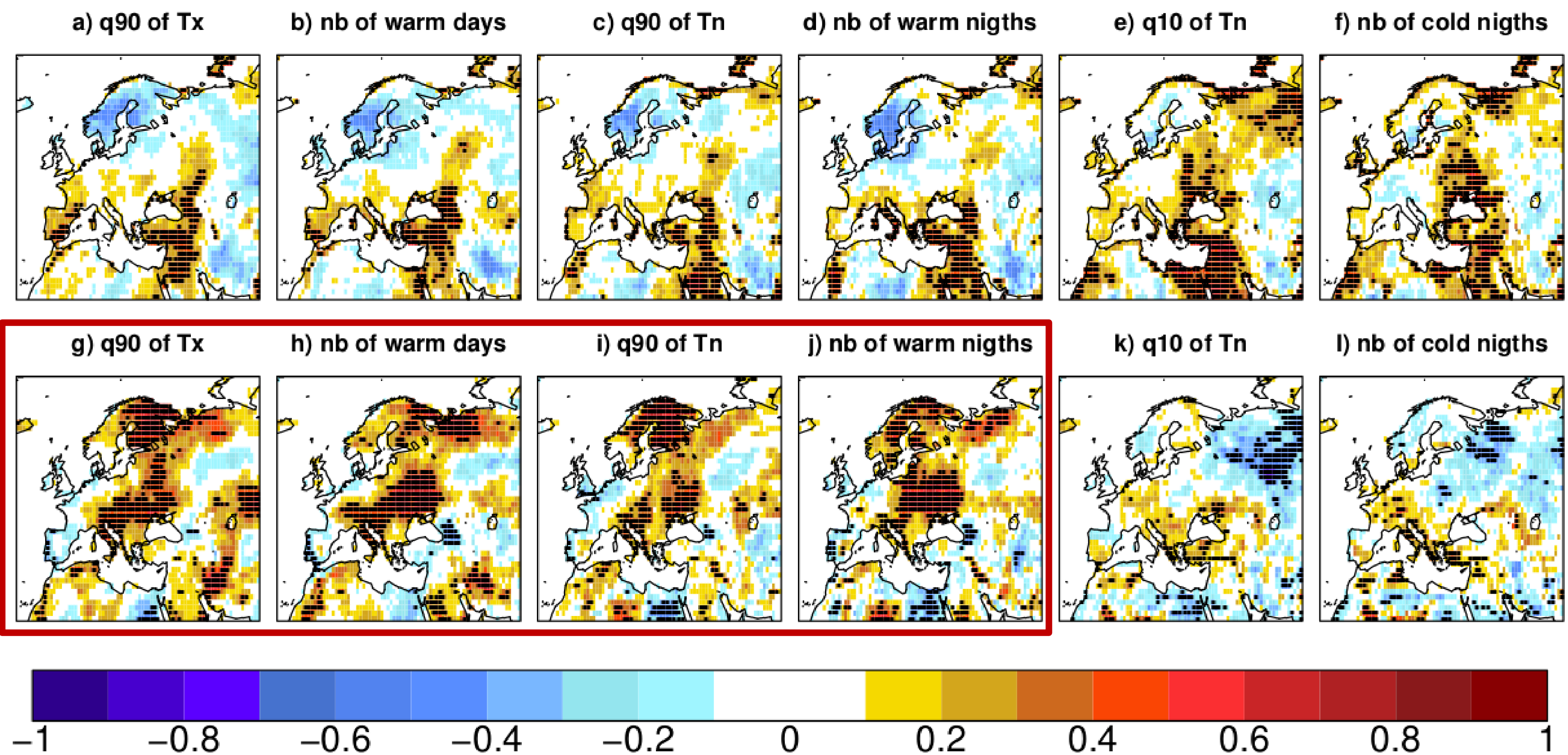
JJA near-surface temperature correlation of the ensemble mean from experiments with a climatological (top) and difference with one with realistic (bottom) land-surface initialisation. Results for EC-Earth2.3 started in May over 1979-2010.



Prodhomme et al. (2015, Clim. Dyn.)

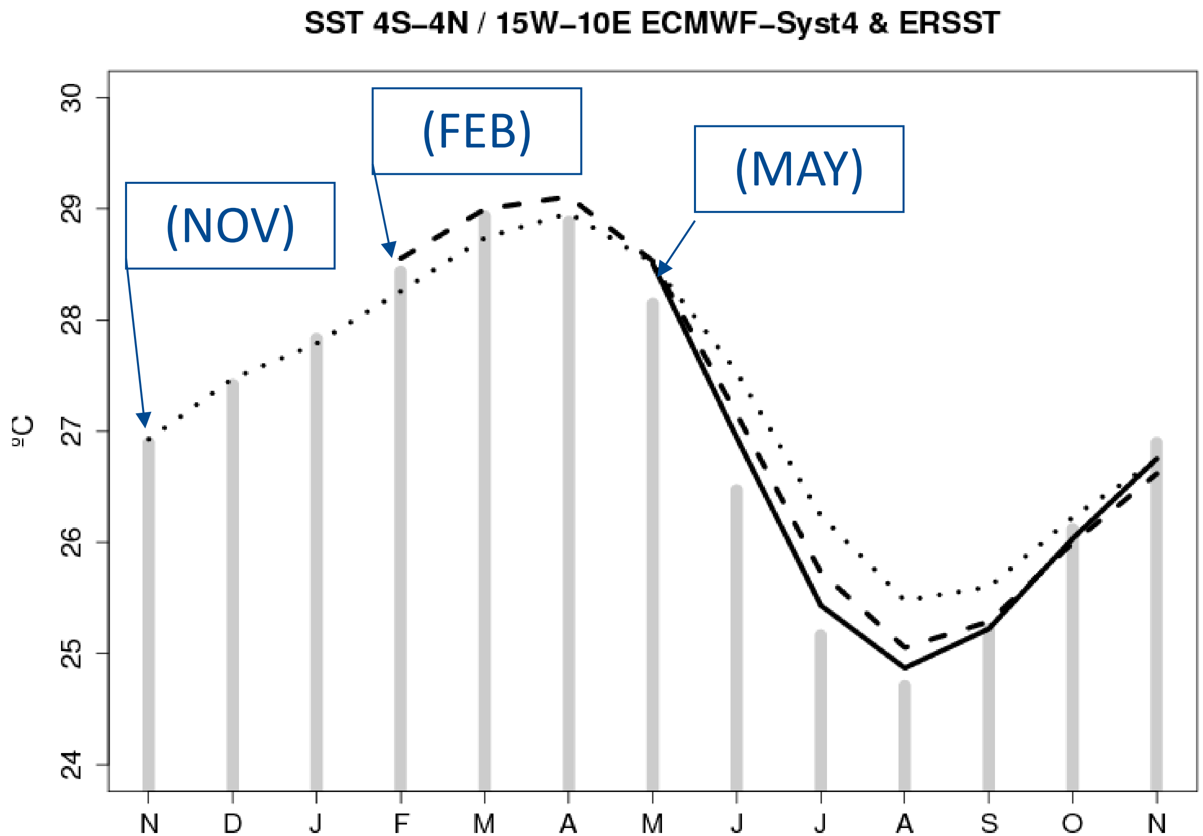
Drift and systematic error

- All the work above is based on forecast and observed anomalies, without appropriate consideration of the climate characteristics.
- Forecast anomalies are computed as differences from a model climatology. Observational reference anomalies use an observational climatology for the same period.
- The model climatology is different for each start date because the model drifts from the initial conditions based on observations towards the model stationary climate.
- In this context, systematic errors are a moving target.
- The characteristics of the drift depend on the variable considered and can be either very fast (SLP, days) or very slow (ocean salinity, decades).
- The stationary systematic errors (those analysed in the CMIP exercises) are not necessarily relevant for climate predictions.

Drift in the tropical Atlantic

Tropical Atlantic (4ºS-4ºN, 15ºW-10ºE) averaged SST 1982-2008 for ERSST (observations, grey bars) and ECMWF System 4 with start dates May, February (3-months ahead), and November (6 months).

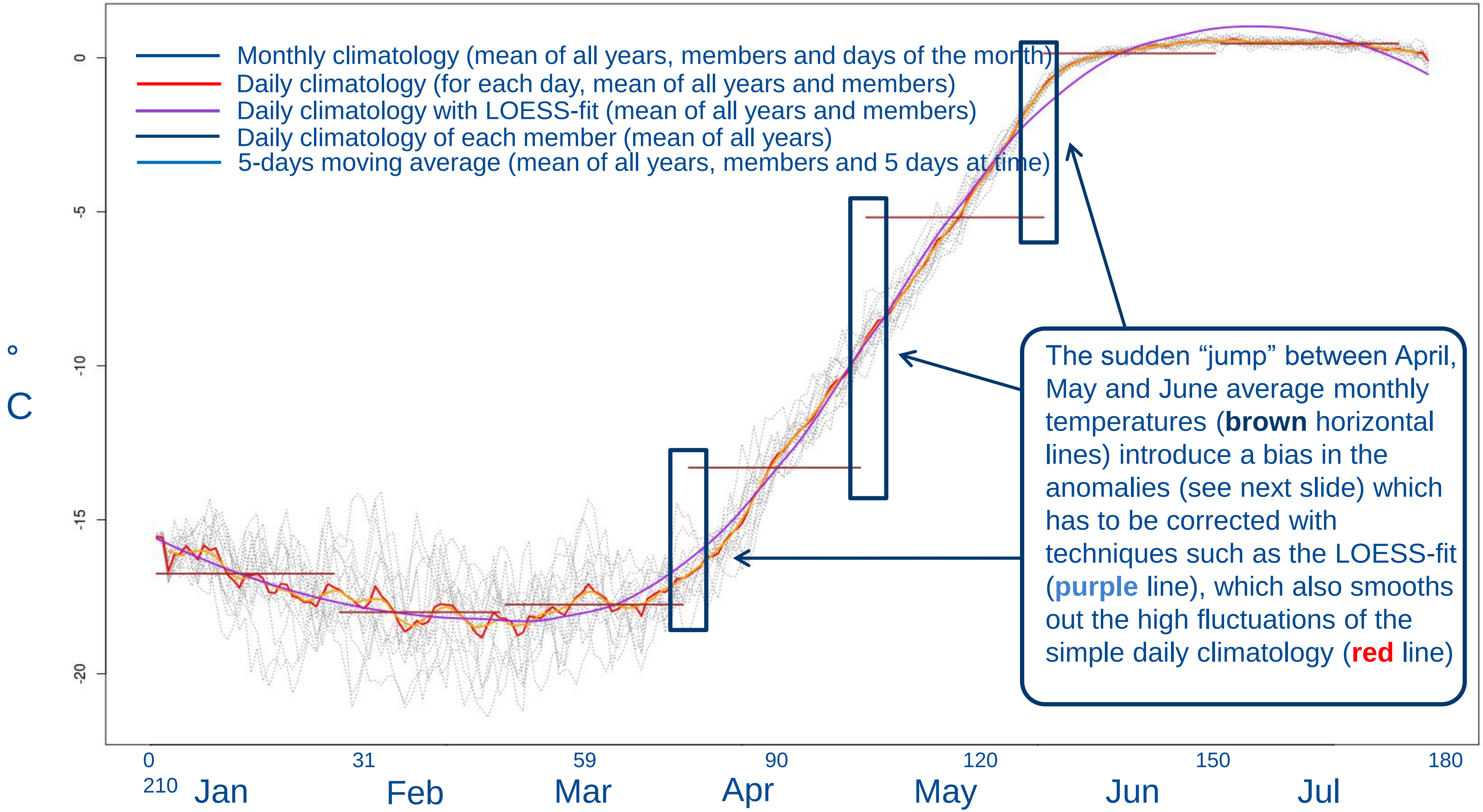
The drift is the consequence of the set of physical processes the model uses to shift from the initial conditions to its attractor.



Doblas-Reyes et al. (2013, WIRES Clim. Ch.)

Drift estimates: daily data

Daily climatology of two-metre temperature data from ECMWF S4, 1982-2013.



Cortesi et al. (2016, BSC Tech Memo)

Drift estimates: daily data

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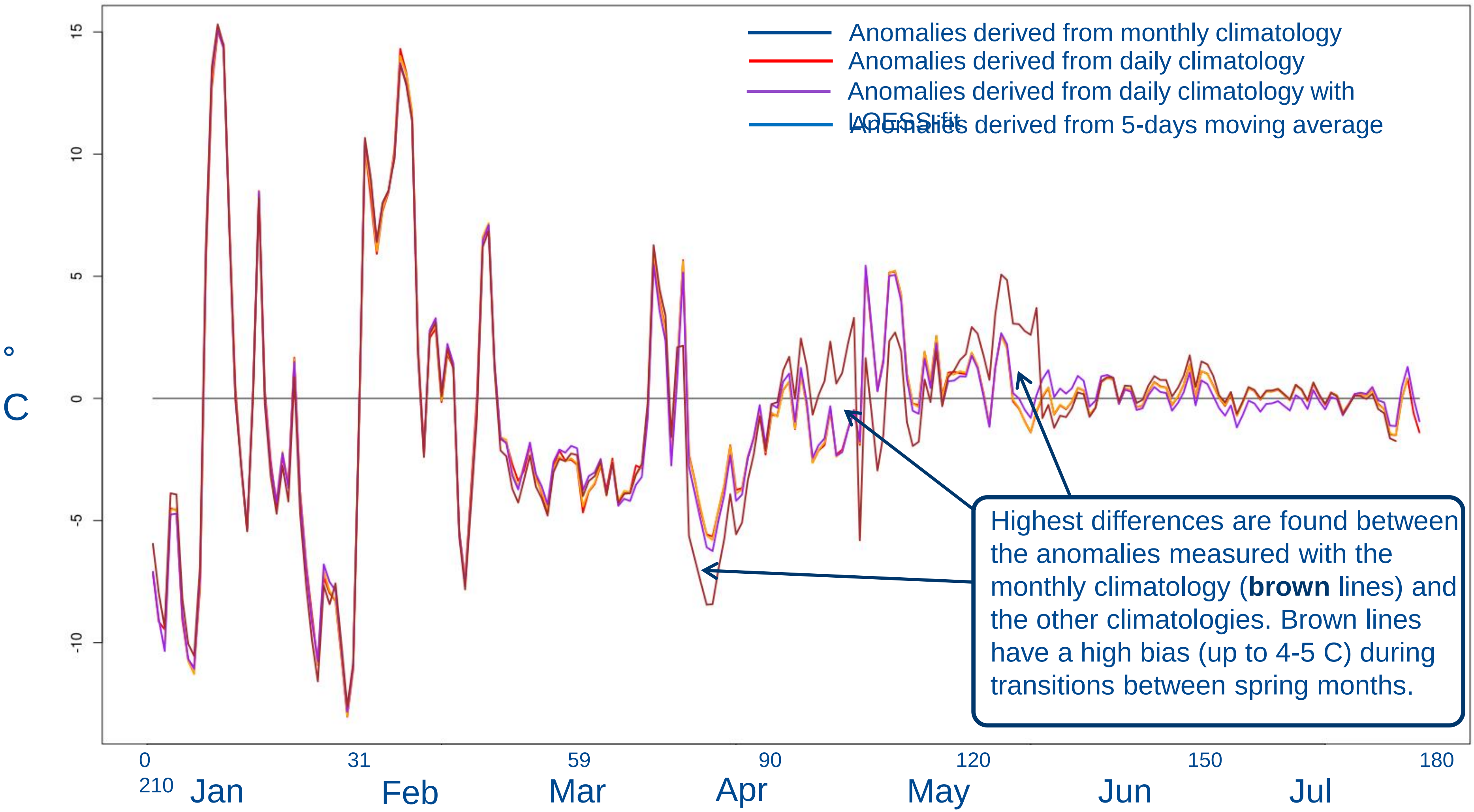
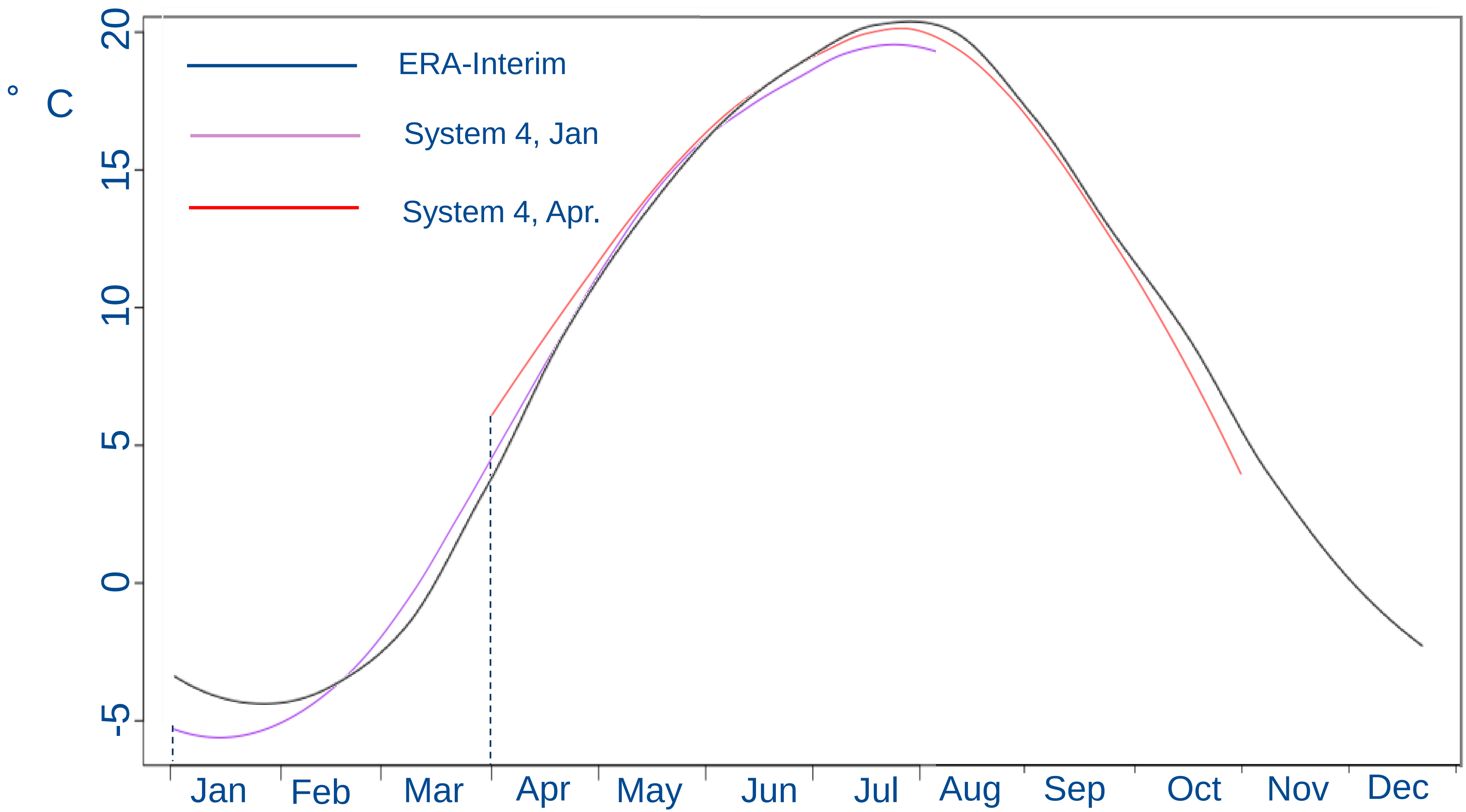
Anomalies from the daily climatology of two-metre temperature data from ECMWF S4, 1982-2013.



Cortesi et al. (2016, BSC Tech Memo)

Drift estimates: daily data

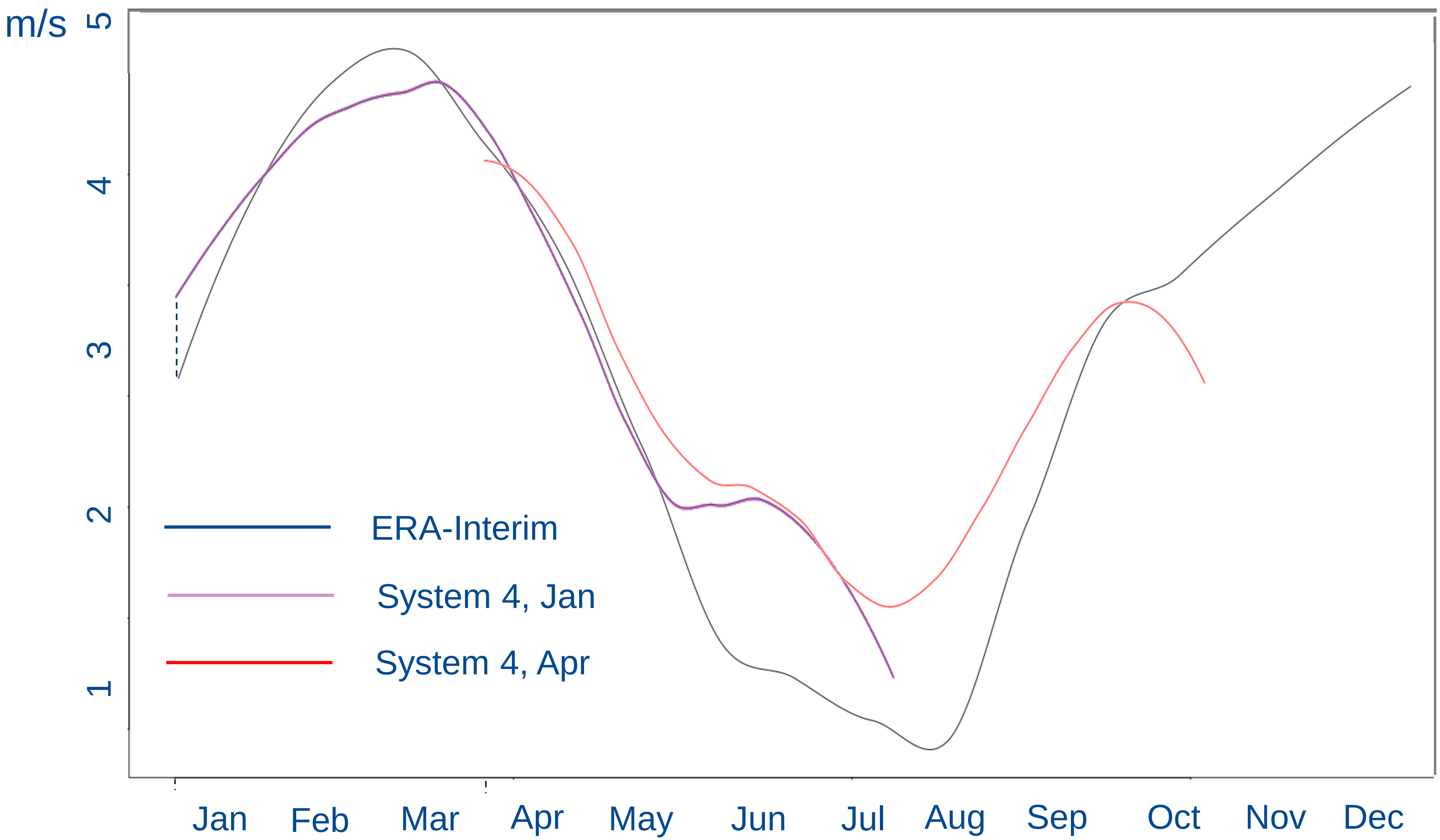
Climatology from the daily climatology of 2m temperature data from ECMWF S4 and ERA-Int for January and April start dates, 1982-2013.



Cortesi et al. (2016, BSC Tech Memo)

Drift estimates: daily data

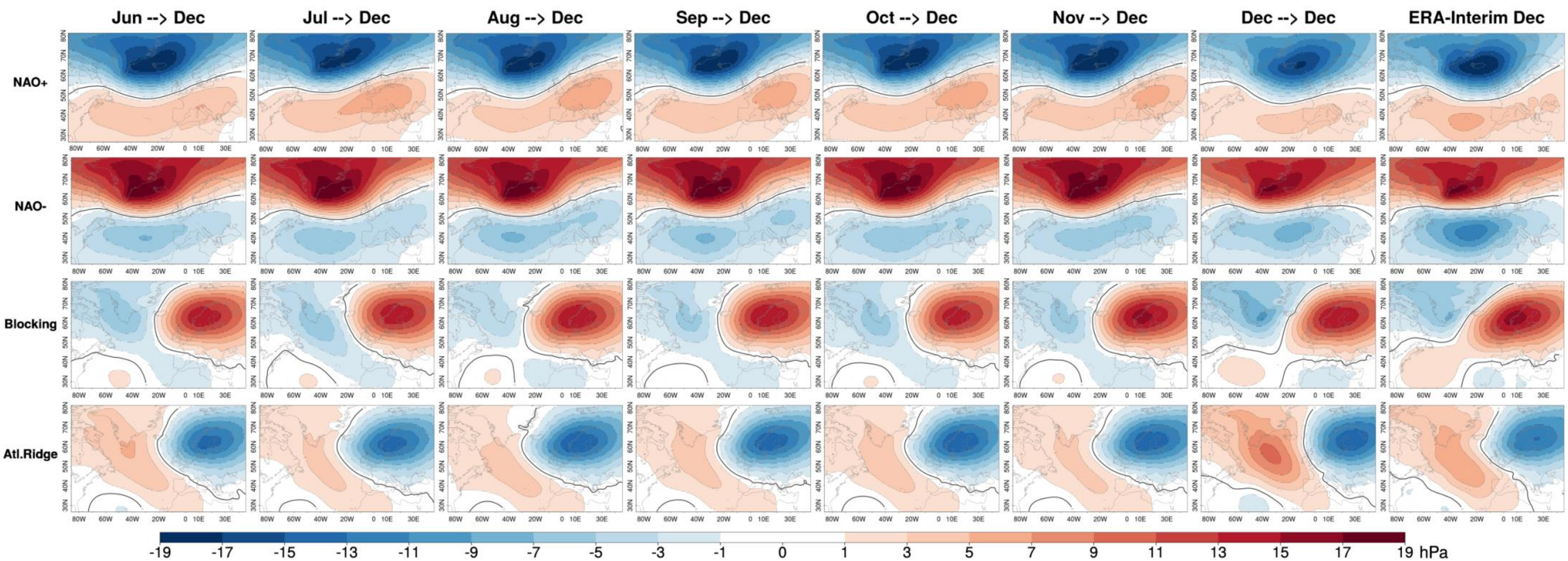
Climatology from the daily climatology of 10m wind speed data from ECMWF S4 and ERA-Int for January and April start dates, 1982-2013.



Cortesi et al. (2016, BSC Tech Memo)

Drift estimates: variability

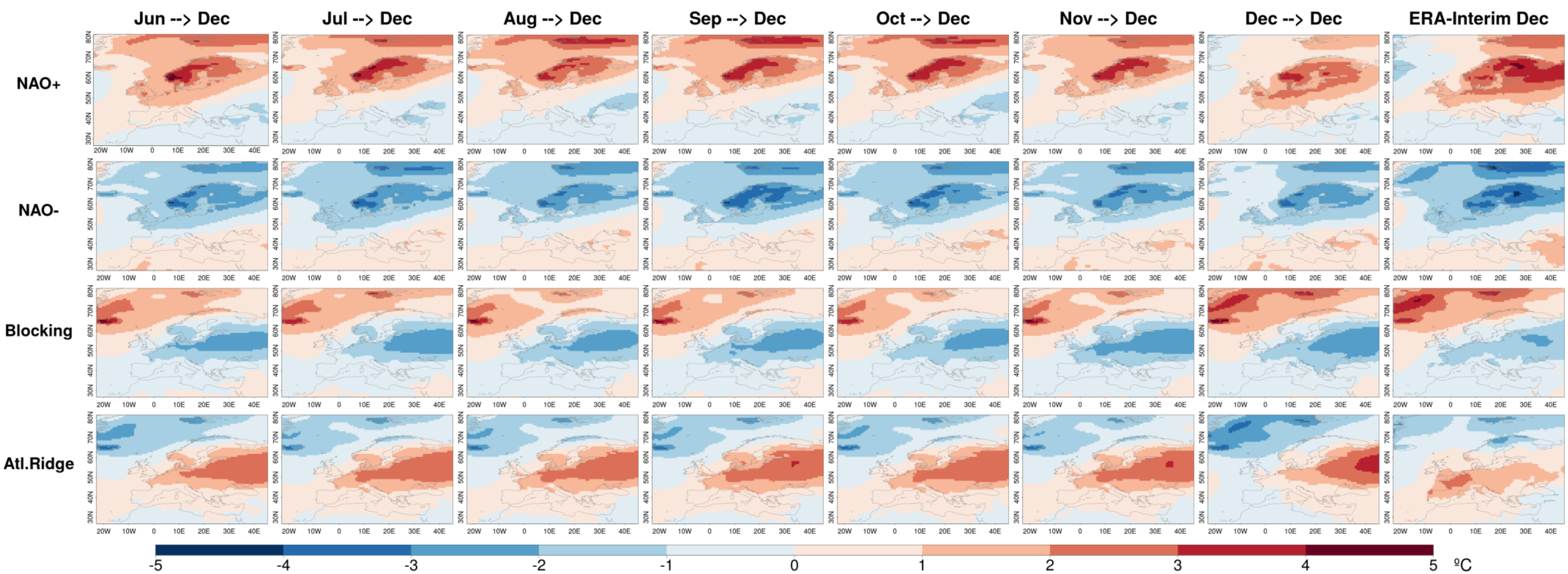
North Atlantic weather regimes (based on sea level pressure) for December for ERAInterim (right) and the ECMWF System 4 hindcasts over 1981-2014 with decreasing lead time from left to right (from six to zero months).



Cortesi et al. (2016, BSC Tech Memo)

Drift estimates: variability

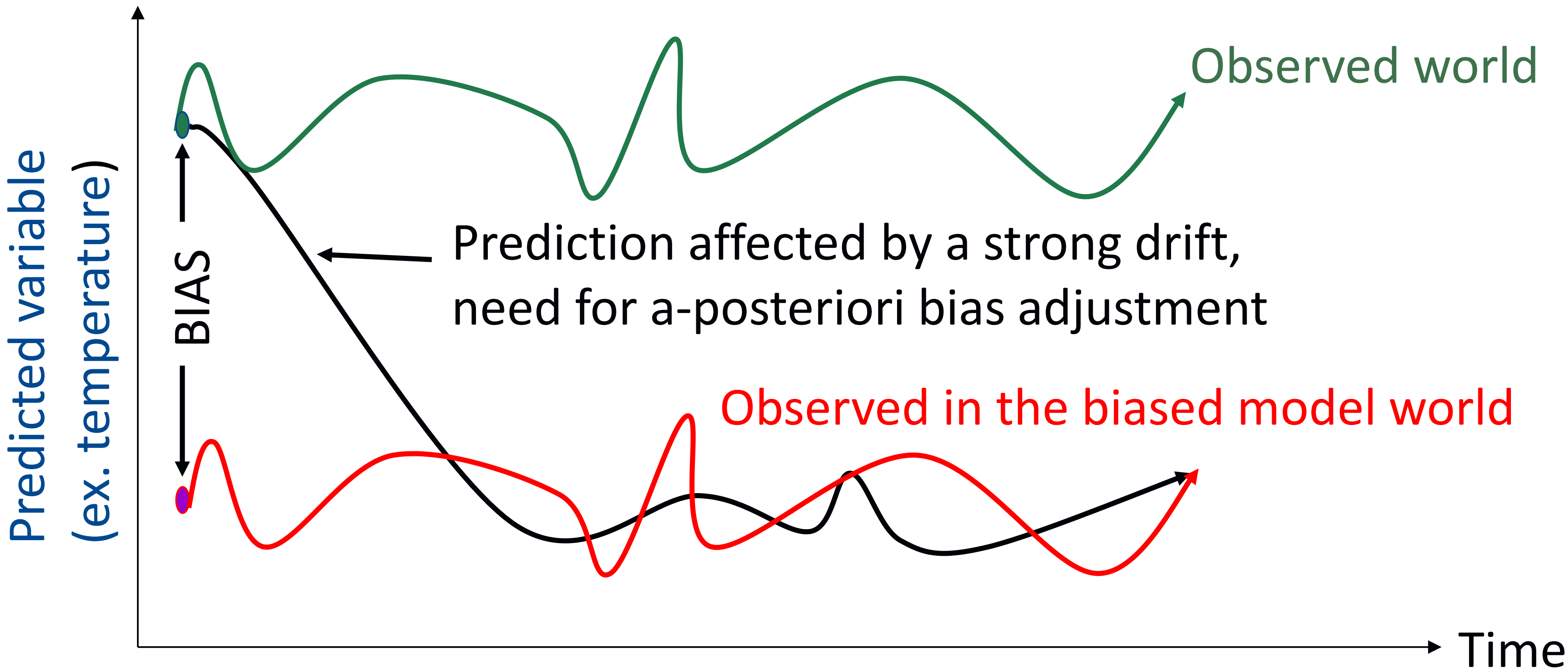
Impact of the North Atlantic weather regimes (based on sea level pressure) on two-metre temperature for December for ERAInterim (right) and the ECMWF System 4 hindcasts over 1981-2014 with decreasing lead time from left to right (from six to zero months).



Cortesi et al. (2016, BSC Tech Memo)

A potential solution: anomaly initialisation

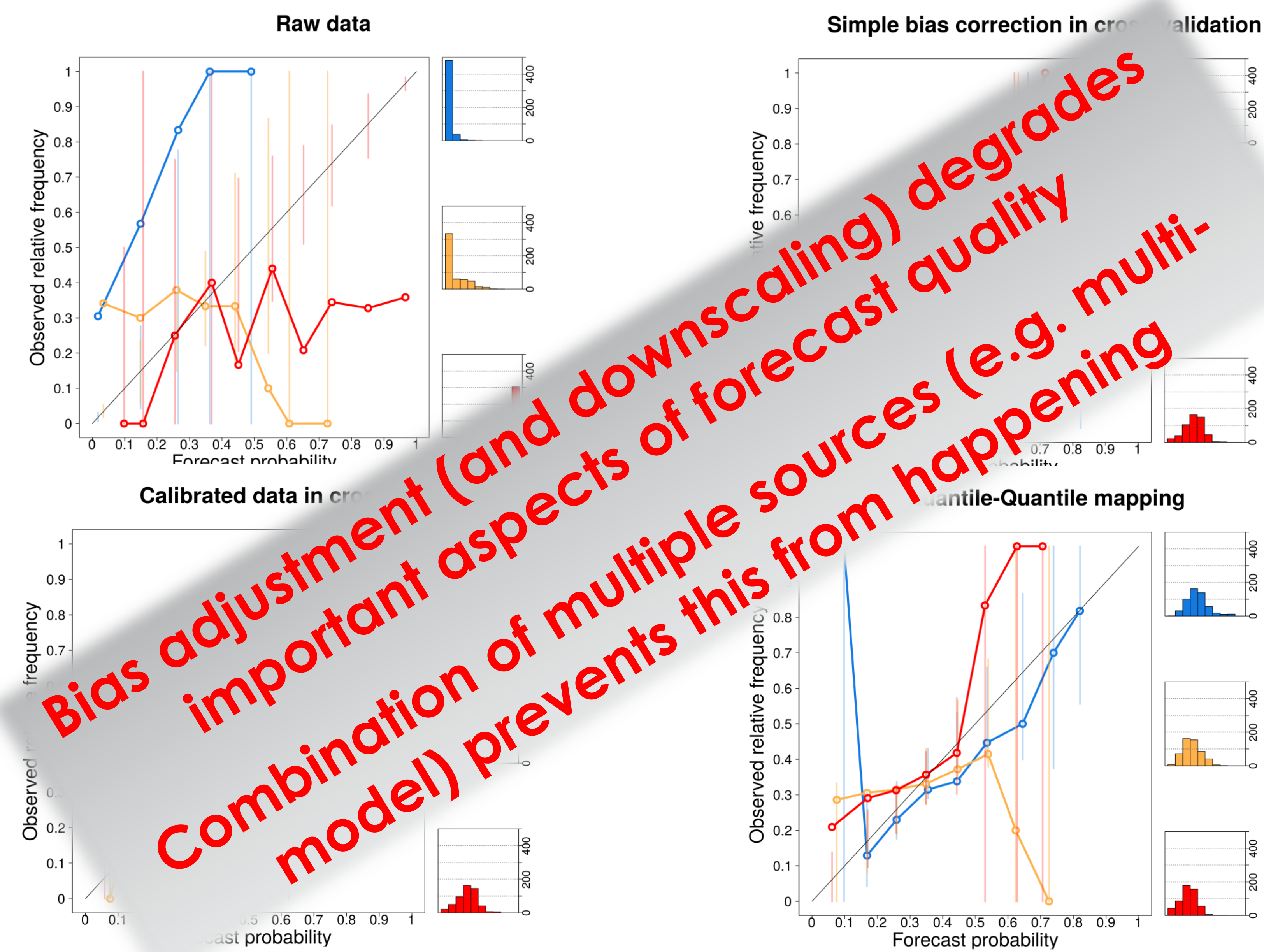
Up to now all the examples used full-field initialisation.



A prediction can also be formulated with anomaly initialisation: start from the observations imposed on an estimate of the model climate.

Alternatives are flux correction, anomaly coupled and super-model.

Bias correction: reliability



Bias adjustment (and downscaling) degrades important aspects of forecast quality

Combination of multiple sources (e.g. multi-model) prevents this from happening

Torralba et al. (2017, JAMC)

Drift uses: uncovering model errors

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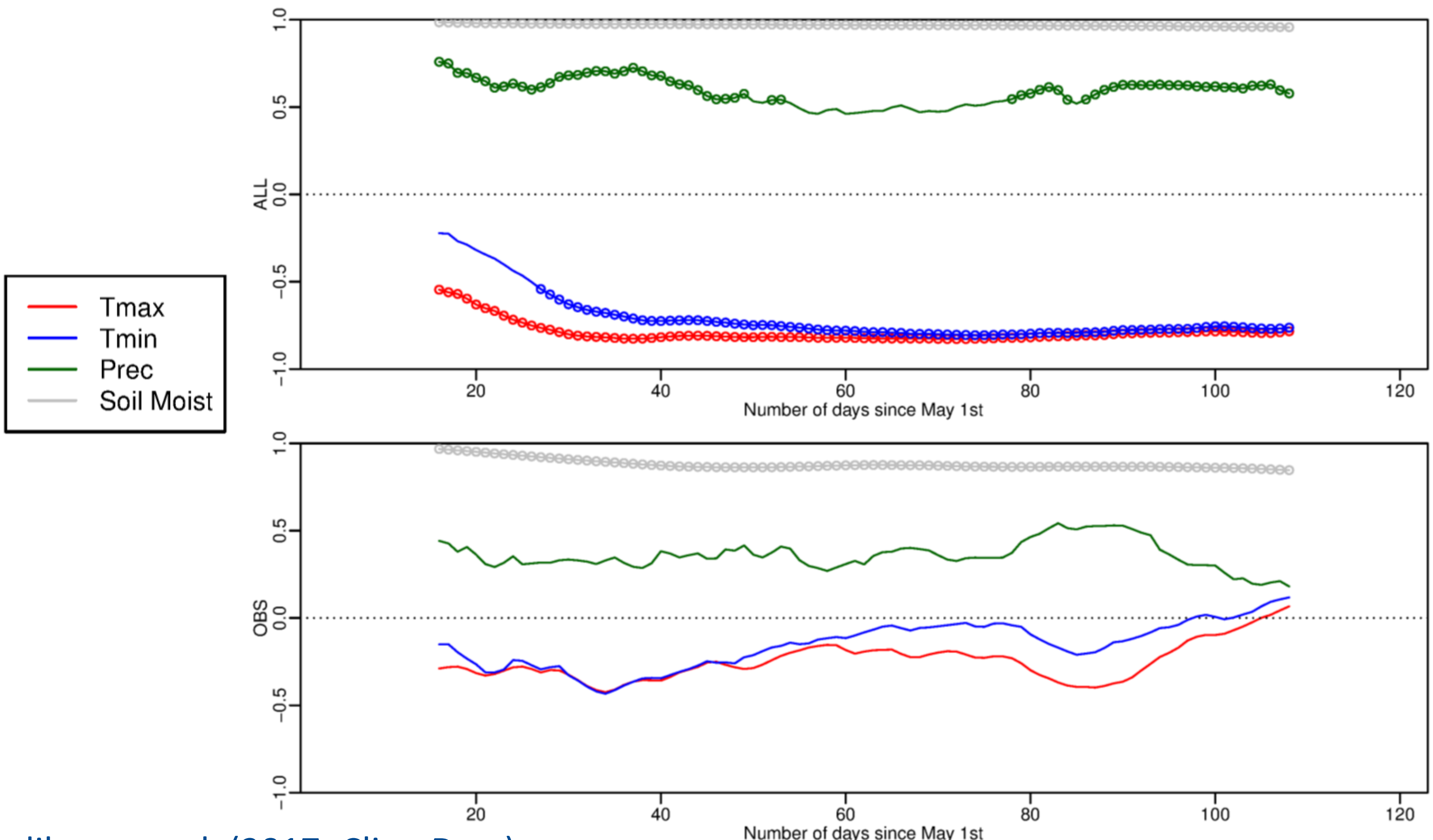
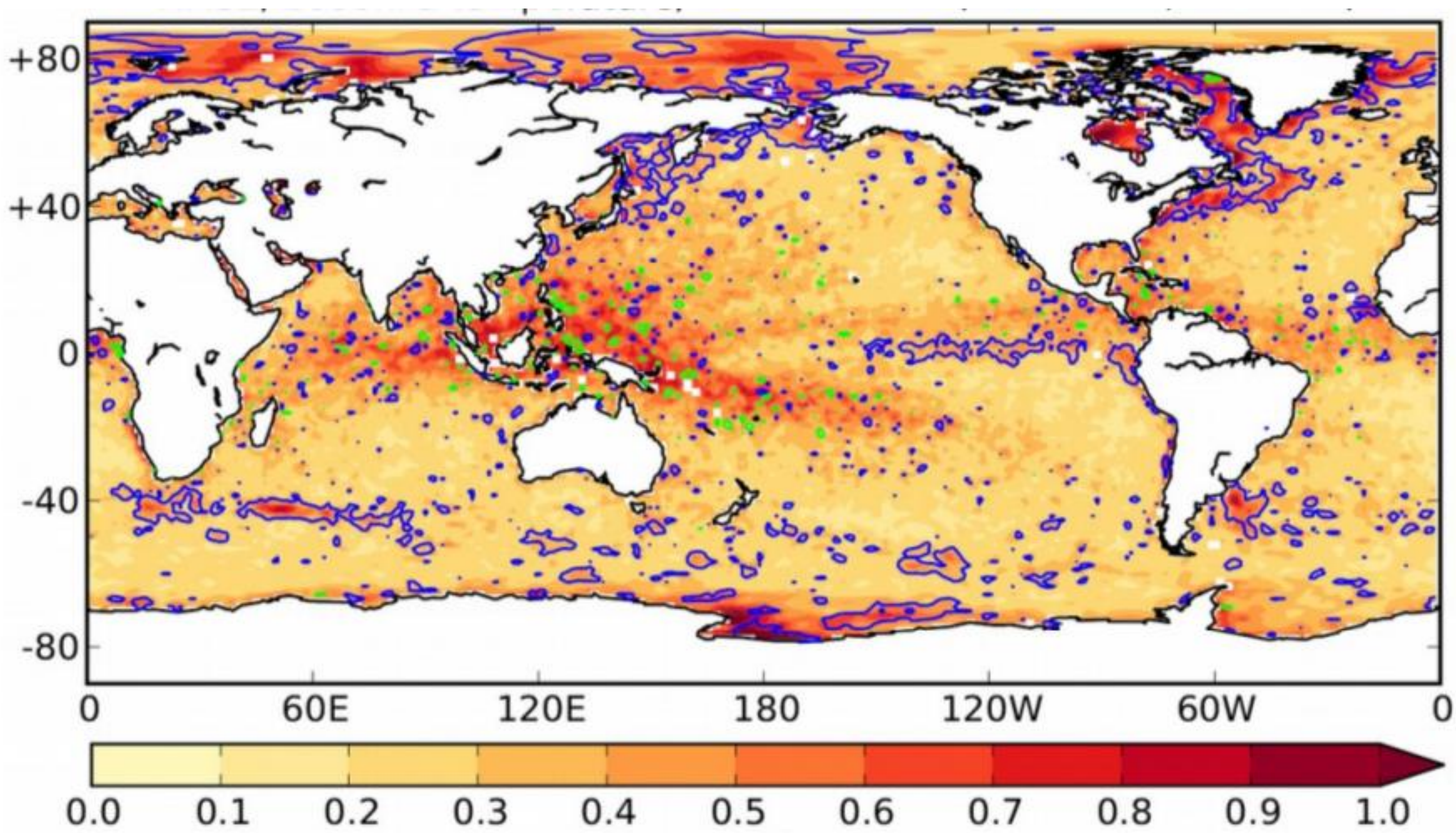
Correlation between 1st of May total soil water content and 31-day running mean of variables from the SPECS multi-model seasonal forecast (top) and ERAInt (bottom) over North American Great Plains.

The model shifts quickly to excessive land-atmosphere coupled state.



Ardilouze et al. (2017, Clim. Dyn.)

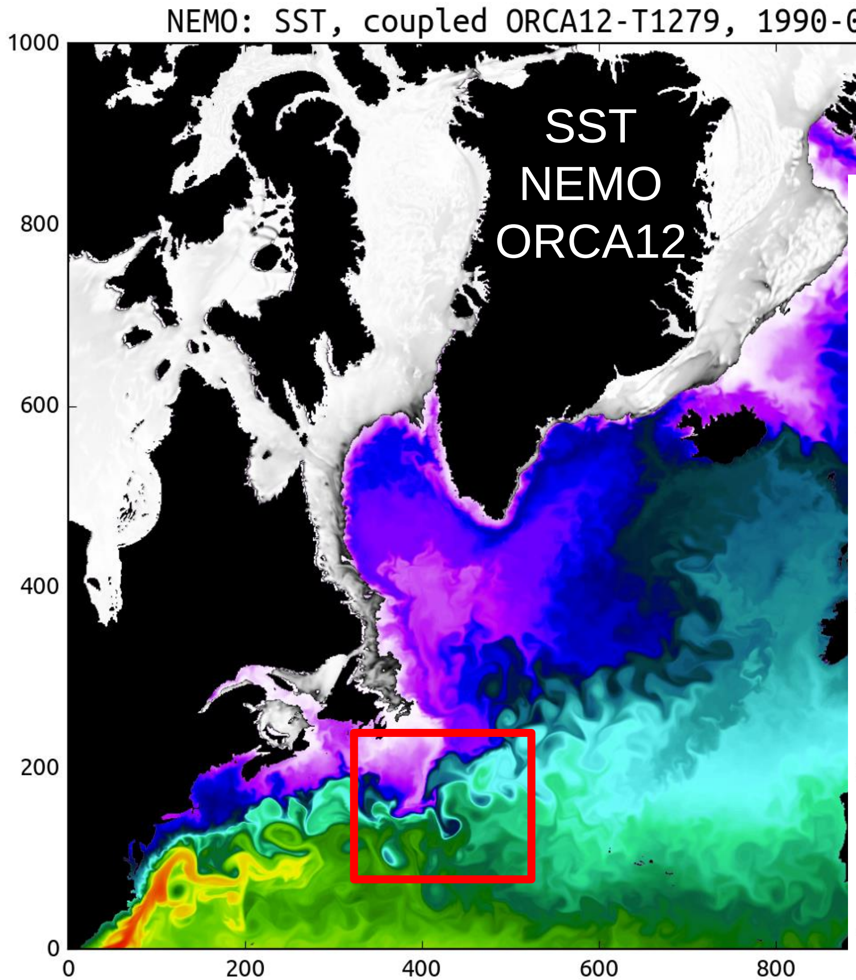
1000 hPa temperature RMSE (versus its own analysis) after 12 hours in the coupled forecasts initialised from ECMWF's CERA (coupled, shades) and uncoupled (blue contours for RMSE increases) analysis.

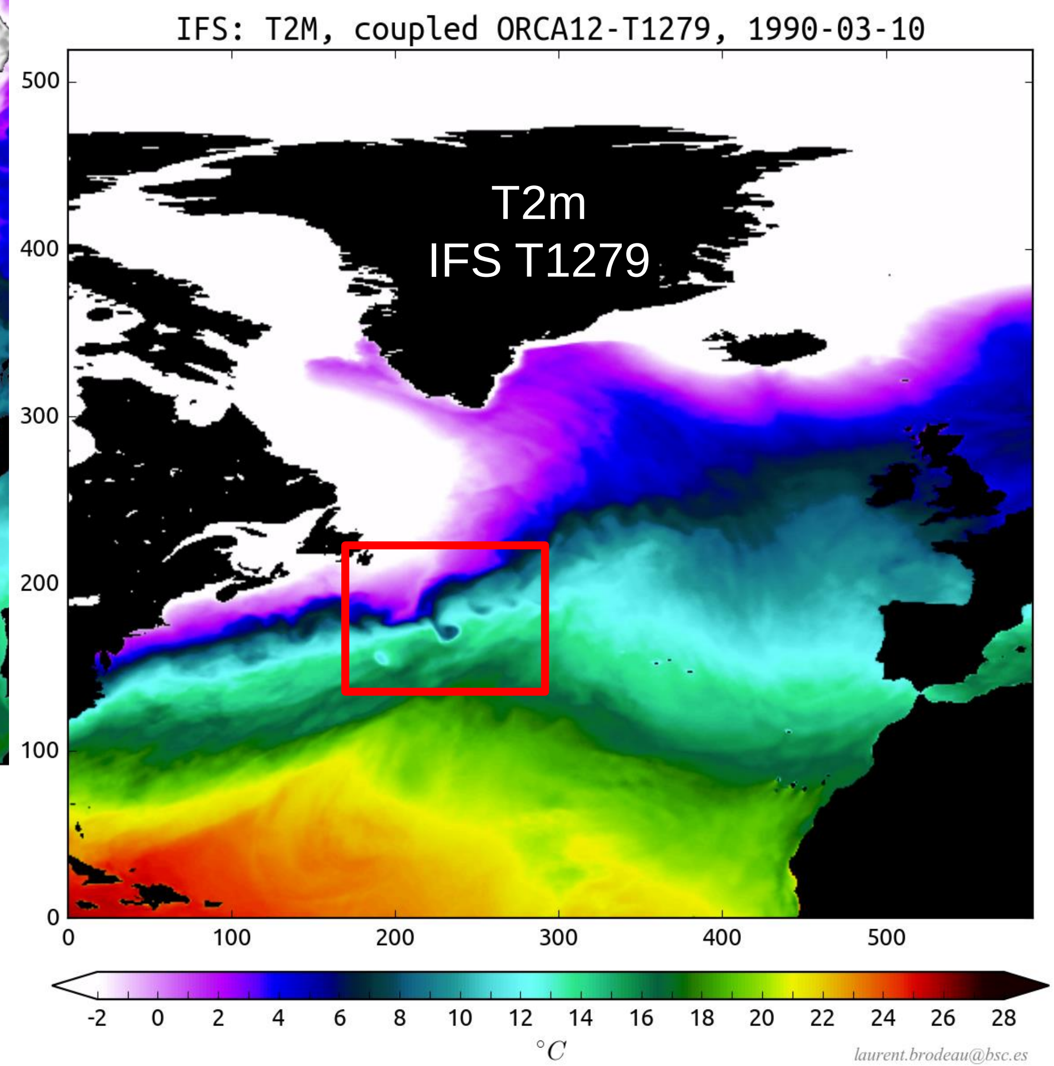


P. Laloyaux (2016, SPECS/PREFACE/WCRP drift meeting)

High-resolution global modelling

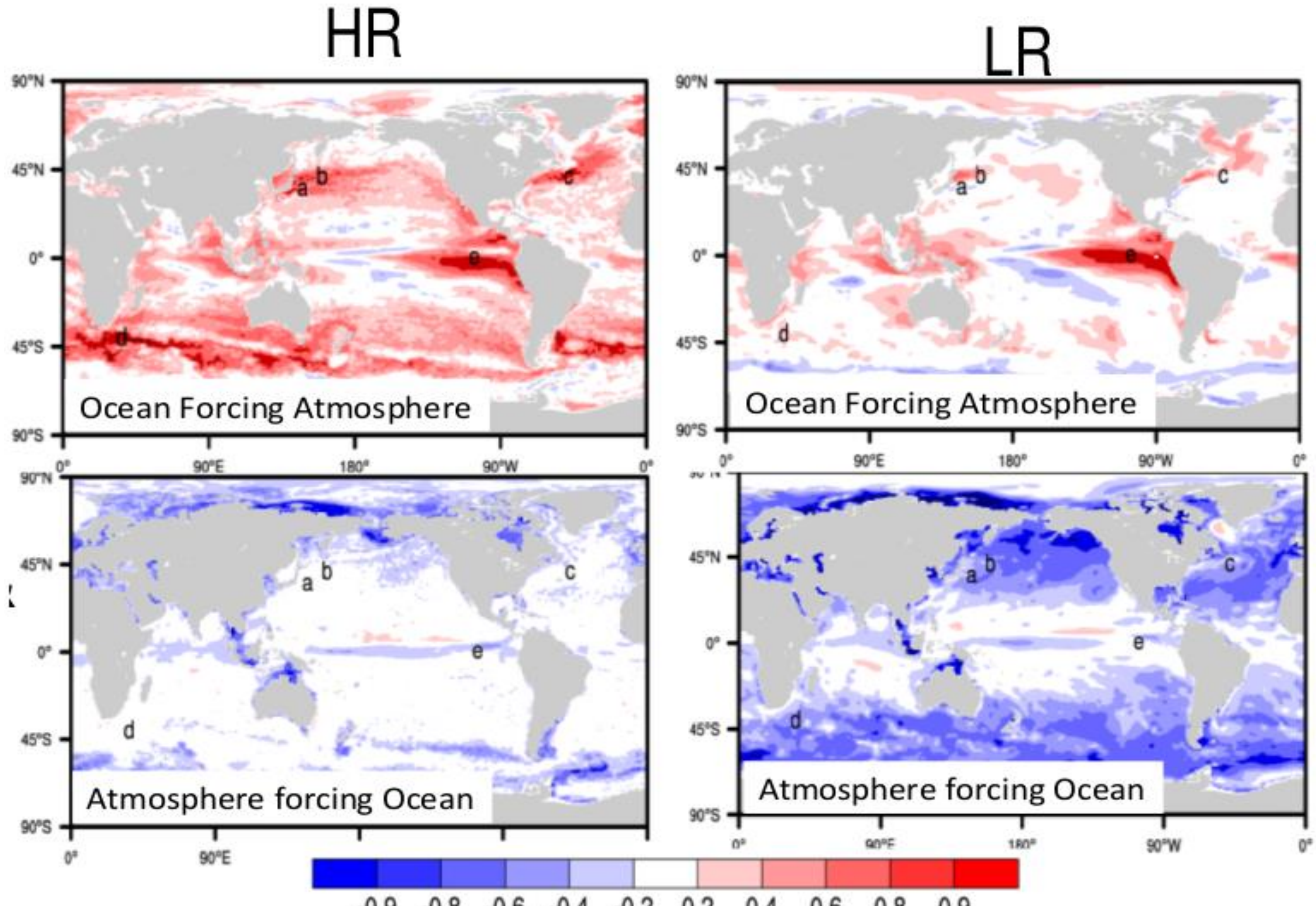
EC-Earth GLOBAL ORCA12-T1279
(ocean and atmosphere at ~15 km!)





High-resolution global modelling

Lagged correlation SST-heat flux in CAMS4, high (0.1º) and standard (1º) ocean resolution.



Kirtman (2017)

Summary

- Drift, which is not necessarily monotonic, is the result of the model tending towards its own attractor. Initial shock is the result of the model rejecting a part of the initial conditions.
- Both initial conditions and model systematic error are important to set the characteristics of the drift.
- Current drift analysis uses initialised predictions, partial coupling experiments, flux correction, anomaly coupling, etc.
- Coupled data assimilation and high-resolution global modelling offer a promising way forward.
- The idea that resides behind the relevance of the drift is the expected relationship between forecast quality and model fidelity.
- Important issues like handling multi-models, multi-variate bias adjustment, observational uncertainty, bias-adjustment error propagation, what current climate actually is, … need more time
- Related projects: VISCA (H2020) and QA4Seas (C3S).